First Experiences with Porting a Multigrid Solver to the CBEA

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Outline

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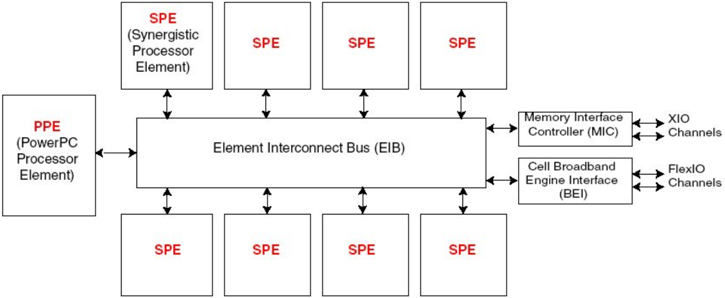
- It has been designed by the Cell consortium (IBM, Sony and Toshiba) and is used in the Playstation 3

Architecture



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- Mailbox and signaling mechanisms available as well

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Besides the internal on-chip parallelism, various Cell chips can be used via MPI.

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3. Replace Altivec-intrinsics by SPU-intrinsics and implement copying from and to local store on the SPE (Multi-buffering is necessary, here)

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- Extension of approach for more general problems possible (algebraic multigrid)

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- Data is ditributed amongst SPEs in the $(d-1)$th dimension to load large consecutive chunks from global main memory
- Pipelining well-suited to improve computation to load/store ratio (chaining smoothing iterations)

Step 1: Plain C program

```
float u[N+2][N+2][N+2];
float f[N+2][N+2][N+2];
float tmp[N+2][N+2][N+2];
...
float f1_6 = 1.0/6.0;
...
for (iter=0;iter<MAXITER;iter++) {
  for (i=1;i<N+1;i++) {
    for (j=1;j<N+1;j++) {
      for (k=1;k<N+1;k++) {
        tmp[i][j][k] = f1_6 * (u[i][j][k-1] + u[i][j][k+1] +
                               u[i][j-1][k] + u[i][j+1][k] +
                               u[i-1][j][k] + u[i+1][j][k] +
                               f[i][j][k]);
      }
    }
  }
}
```

Step 2: C program plus Altivec intrinsics

```
vector float u[N/4+2][N+2][N+2];
vector float f[N/4+2][N+2][N+2];
vector float tmp[N/4+2][N+2][N+2];
...
vector float zero, sl, sr, fac;
...
for (iter=0;iter<MAXITER;iter++) {
    for (i=1;i<N/4+1;i++) {
        for (j=1;j<N+1;j++) {
            for (k=1;k<N+1;k++) {
               tmp[i][j][k] = f[i][j][k];
               sl = vec_sld(u[i][j][k],u[i+1][j][k],4);
               sr = vec_sld(u[i-1][j][k],u[i][j][k],12);
               tmp[i][j][k] = vec_add(tmp[i][j][k],u[i][j-1][k]);
               tmp[i][j][k] = vec_add(tmp[i][j][k],u[i][j+1][k]);
               tmp[i][j][k] = vec_add(tmp[i][j][k],u[i][j][k-1]);
               tmp[i][j][k] = vec_add(tmp[i][j][k],u[i][j][k+1]);
               tmp[i][j][k] = vec_madd(fac,tmp[i][j][k],zero);
}   }   }   }
```

Step 3: SPU C program (1/3)

```
...
copy_data(my_u[0],u+(m+2)*(       ystart),(m+2)*(yend-ystart+2),
          bufidx,MFC_GET_CMD);
copy_data(my_u[1],u+(m+2)*(   n+2+ystart),(m+2)*(yend-ystart+2),
          bufidx,MFC_GET_CMD);
copy_data(my_u[2],u+(m+2)*(2*n+4+ystart),(m+2)*(yend-ystart+2),
          bufidx,MFC_GET_CMD);
copy_data(my_f[0],f+(m+2)*(       ystart),(m+2)*(yend-ystart+2),
          bufidx,MFC_GET_CMD);

/* Jacobi iteration */
for (int k=1; k<=o; k++) {
  nextidx = bufidx ^ 1;
  /* Copying data for next plane */
  copy_data(my_u[3],u+(m+2)*((k+2)*(n+2)+ystart),
            (m+2)*(yend-ystart+2),nextidx,MFC_GET_CMD);
  copy_data(my_f[1],f+(m+2)*((k+1)*(n+2)+ystart),
            (m+2)*(yend-ystart+2),nextidx,MFC_GET_CMD);
```

Step 3: SPU C program (2/3)

```
/* Doing computation on current plane */
 for (int j=1; j<=yend-ystart; j++) {
   for (int i=1; i<=m; i++) {
    sr1 = spu_rlqwbyte(my_u[1][i  +(j  )*m],12);
    sr2 = spu_slqwbyte(my_u[1][i  +(j-1)*m],12);
    sr = spu_madd(sr1,last_3,sr2);
    sl1 = spu_rlqwbyte(my_u[1][i  +(j+1)*m],4);
    sl2 = spu_slqwbyte(my_u[1][i  +(j  )*m],4);
    sl = spu_madd(sl1,last_1,sl2);

    tmp1 = spu_add(sl,sr);
    tmp2 = spu_add(my_f[0][i+j*m],tmp1);
    tmp3 = spu_add(my_u[1][i-1+(j  )*m],my_u[1][i+1+(j  )*m]);
    tmp4 = spu_add(my_u[0][i  +(j  )*m],my_u[2][i  +(j  )*m]);
    tmp5 = spu_add(tmp3,tmp4);
    tmp6 = spu_add(tmp2,tmp5);
    my_tmp[0][i+j*m] = spu_mul(fac,tmp6);
   }
 }
```

Step 3: SPU C program (3/3)

```
/* Swapping pointers */
tmp_ptr = my_u[0];
my_u[0] = my_u[1];
my_u[1] = my_u[2];
my_u[2] = my_u[3];
my_u[3] = tmp_ptr;
tmp_ptr = my_f[0];
my_f[0] = my_f[1];
my_f[1] = tmp_ptr;
tmp_ptr = my_tmp[0];
my_tmp[0] = my_tmp[1];
my_tmp[1] = tmp_ptr;

/* Copying data back */
 copy_data(my_tmp[1],u+(m+2)*(k*(n+2)+ystart),
           (m+2)*(yend-ystart+2),nextidx,MFC_PUT_CMD);
...
```

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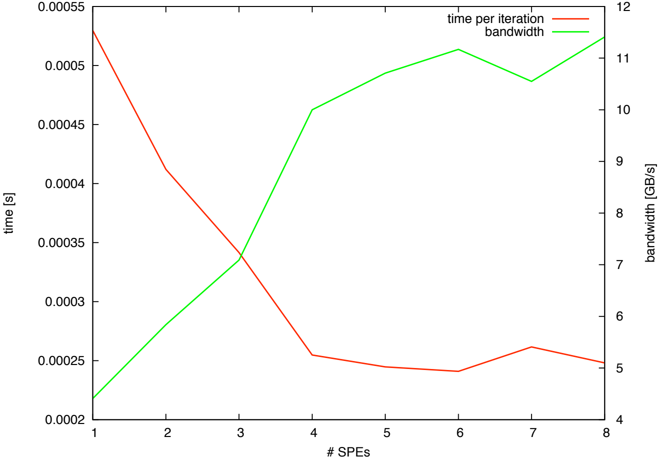
Preliminary results



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- Double precision
- Tools for porting software

First Experiences with Porting a Multigrid Solver to the CBEA

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